Diet for a Blue Planet

Tasty crabs, sold on the dock for $4 per pound, are the first edible success of a novel approach to ocean farming

By JULIE ANN MILLER

A "blue revolution" may soon be upon us, turning the world's oceans into a significant food resource. The oceanographer's typical view of the tropical seas as unproductive deserts, with little potential for plant and animal growth except on occasional reefs, is being challenged by scientists at the Smithsonian Institution in Washington, D.C.

In research that began with the construction of a living coral reef at the Smithsonian's Museum of Natural History (SN: 10/18/80, p. 250) and that now extends to several ocean sites in the Caribbean, scientists have demonstrated a biological productivity surpassing that of the richest wheat-growing areas of the Midwest. The researchers are beginning to devise methods to employ that productivity to provide a much-needed boost to island communities.

A large tropical spider crab has just passed with flying colors the first feasibility test of this strategy. The West Indian crab *Mithrax spinosissimus*, also called Caribbean king crab, has now been grown in open cages floating in the sea. Smithsonian's Walter Adey, who is leading the research, believes that a profitable mariculture industry could be developed almost immediately as a source of income to impoverished Caribbean fishermen. But other observers are more skeptical about the practicality of large-scale crab farming and are waiting for reports by economists.

There is no disagreement about the flavor of the crab. Tim Goertemiller, one of Adey's colleagues, describes it as sweeter than blue crab but with a texture more like lobster. Adey says, "It tastes as good as Alaskan king crab." This taste should guarantee the Caribbean crab a sizable market, because the Alaskan king crab fisheries are failing due to a shortage of crabs. Previously, the Caribbean crab was eaten only occasionally because it is nocturnal and hides in crevices at ocean depths of 80 to 90 feet.

Most ocean areas have long been considered very limited in plant productivity and fisheries potential. The major limitation was thought to be the low level of nutrients, particularly nitrogen and phosphorus, dissolved in the sea. These nutrients are so low that scientists have needed special methods to measure them and the levels of biological production they support in the laboratory.

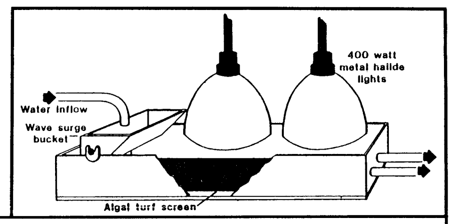
Now Adey reports that under certain conditions, in the laboratory and in the sea, low nutrient concentrations of seawater do not significantly limit plant growth, and "extraordinarily high levels of plant production" are possible.

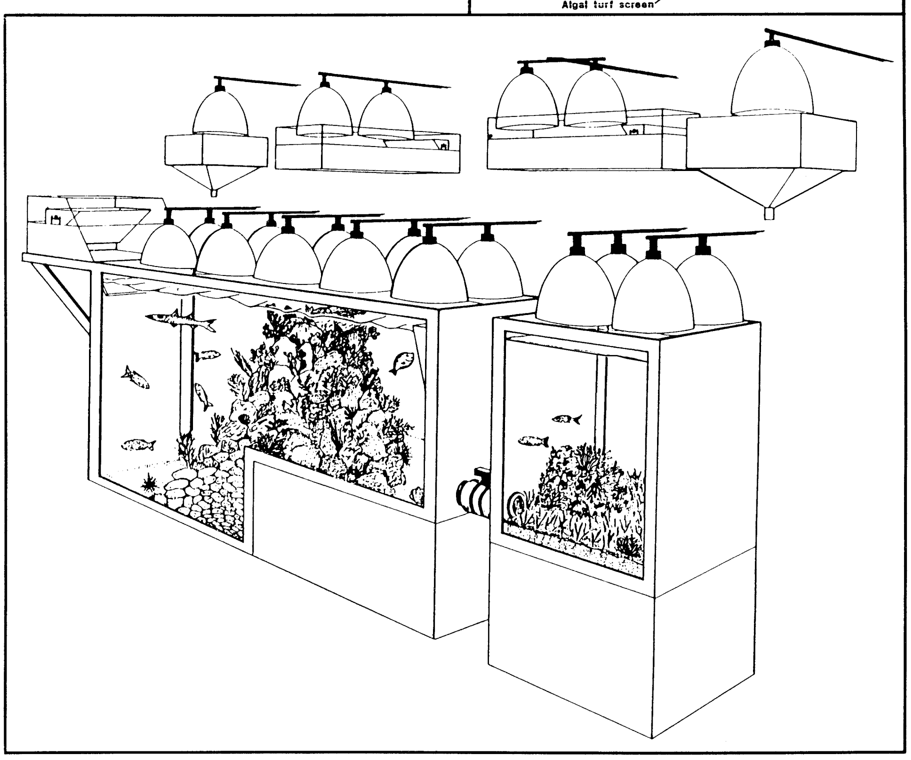
"Current and wave action lead to increased productivity," Adey says. "When you harvest [plant material] month after month and raise animals based on that harvest, then you can't deny it."

Adey's new view of ocean productivity arose from his studies of coral reefs. Coral reefs have long been recognized as among the most productive ecosystems on earth — but they have been considered to be oases in a desert of tropical sea. "In spite of their supposed high productivities and their importance to local, small island populations," Adey says, "in a global sense coral reefs have been regarded as biological curiosities." As productive as they can be, they cannot themselves be a significant direct source of human food. They are small and fragile, so they are easily damaged by attempts to harvest the plant life.

Biologists have puzzled over what is special about the reefs. The most common answer has been a rapid recycling of nutrients by the coral reef community. But now Adey has proposed that the crucial factor is the washing of the waves over stationary plants, such as the filamentous algae.

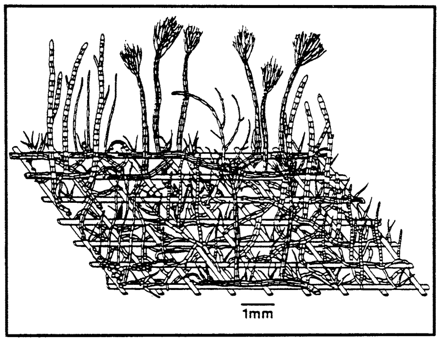
The new method of sea farming, which takes advantage of the wave action, employs algae grown on shallowly submerged plastic screens. Similar screens were first used by Adey and colleagues for the coral reef at the Museum of Natural History to avoid chemical imbalances. In





Photos & Illustrations: Adey/Smithsonian Museum of Natural History

The luxuriant growth of filamentous algae on plastic screens was first noted at the coral reef exhibit at the Smithsonian Museum of Natural History. There, water circulated between tanks containing algae on screens, called scrubbers, which were illuminated at night (see detail at top), and the main coral reef tank, which was illuminated during the day.



Detail of typical algal turf scrubber (far left). Above, screens of algae stretch across a lagoon; mariculture specialist Karl Porter slips screens of algae into the crab-growing cages.

the museum reef, imbalances can arise during the hours of nighttime darkness, when plants stop photosynthesis but the organisms of the reef community continue to breathe and excrete wastes. The solution was to set up in the museum an additional collection of plants—algae growing on screens—which would be illuminated when the main tank was dark. Water containing wastes and nutrients would circulate between the two sections.

The researchers established lawns of filamentous algae on the plastic screens, called "scrubbers," to serve as the nocturnally active community. These scrubbers, washed with water in circulation with the main coral reef tank, have successfully maintained appropriate levels of carbon dioxide, oxygen, ammonia and nutrients at the museum reef for about five years.

The scientists were surprised at how rapidly the screens filled with algae, growing from spores in the circulating seawater. Every few days they had to scrape plant material from the scrubbers. They soon realized that they were harvesting more than 5 grams dry weight of algae per square meter of screen per day, a productivity on par with the best terrestrial agriculture.

Because the conditions in the museum tank closely reflect those in the ocean, Adey predicted that similar screens would allow growth of large amounts of algae in the tropical seas. He envisioned harvesting of the algae and, on shore, converting it into alcohol or methane fuel.

The two field tests conducted so far have supported Adey's prediction. Algal turfs grown on rafts supporting plastic screens about a foot below the ocean surface near reefs have been highly productive in waters containing low levels of nutrients off Mayaguana Island in the Bahamas and off Grand Turk in the Turks and Caicos Islands. Under some conditions, the screens produced 20 to 30 grams dry weight of algae per square meter per day.

"This plant productivity exceeds any we thought possible," Adey says. "It is amazing to us that month after month, the screens are producing five times as much plant material [per square meter] as midwestern agriculture."

The physical energy supplied by the strong surges of ocean waves is key to the high productivity, Adey says. Imagine how hungry you could become in a swimming

Algal Cuisine

It was with some relief that I discovered that new sea farming techniques are to have us eating crab and escargot rather than algae. Of course, many Japanese gourmets relish those most primitive green plants, and I have a friend who claims to have tasted 15 distinct varieties of algae and to find them all delicious. But when I think of algae, I can't help but remember my high school science fair project, which convinced me that algae are, in general, a dish to avoid.

My project plan was to grow gallons and gallons of algae, dry and pulverize them, then feed the resultant powder to flour beetles. I learned several important lessons from this project: Techniques are not always as they appear in the journals; basic science doesn't always sell; and think twice before eating algae.

The first lesson came while I was making vats of the solution in which the algae were to grow. Following directions in a published paper, I carefully measured each of 10 chemicals and added them to a carboy of distilled water. The first nine chemicals dissolved easily, but on the addition of the tenth, the solution turned yellow and a massive precipitation soon followed. After five attempts with perfectly reproducible results, my biology teacher called the author of the paper. I then learned that the author had in fact only used the first nine chemicals, but added the tenth, for good measure, to the recipe when writing the paper.

So I made a nine-chemical solution, bubbled gas through it, and my algae thrived. I filled little jars with ground algae (I can still recall the acrid taste of the green dust in the air) and added the beetles. Scientifically sophisticated, I had control beetles in white baking flour. Soon the white jars were teeming with all stages of insect life, while the green ones were bare. What went wrong? Again applying my idea of rigorous scientific method, I began spilling out the jars each day and counting the inhabitants and noting their health. I cannot recall the exact results, but I retain a vivid image of lifeless white larvae with their intestinal tracts visible in green.

At a science fair I presented my results with dozens of construction-paper beetles, many overlaid with black Xs. Although I believe my project contained as much independent scientific thought as one can expect from a young teenager, I placed considerably lower than I had in a previous year when I had merely repeated a university laboratory's flashier experiments. Thus I learned early the difficulty in gaining recognition for truly basic research.

But basic research often speaks to practical matters, more or less appropriately. At the science fair, another contestant had devised recipes for algal flour cookies—starting with the same idea as I had, but shortening the food chain more drastically. When I saw the plates of dull green cookies at the exhibit, I was shocked—and I left a self-righteous note warning of the hazards of algal flour to beetles. As far as I know, no one needed a stomach pump or suffered the consequence of deadly green intestine. But to this day, given the choice, I'd rather dine on crab myself and leave the algae for the crustaceans.

—*J. A. Miller*

pool of very thin soup, with only a few chunks of meat and of potato. But your hunger could certainly be satisfied if you were to stand still and scoop up meat and potatoes as waves of the soup continually washed over you.

However great the production of algae, few people crave a diet of algal turf. While algae may eventually be useful as cattle fodder, as a food additive or even as a food, the Smithsonian scientists decided to begin with a different approach. "Why fight food preferences and force algae into the mouths of even hungry people?" Adey asks. "We decided to shoot for an animal that everyone is going to love to eat."

The search was on for a relatively large "grazer" — some highly palatable marine animal that thrives on an algal turf. In biological terms, short food chains are both more efficient and simpler to develop in mariculture than long ones. Thus the scientists wanted the shortest chain possible: algae → grazer → human.

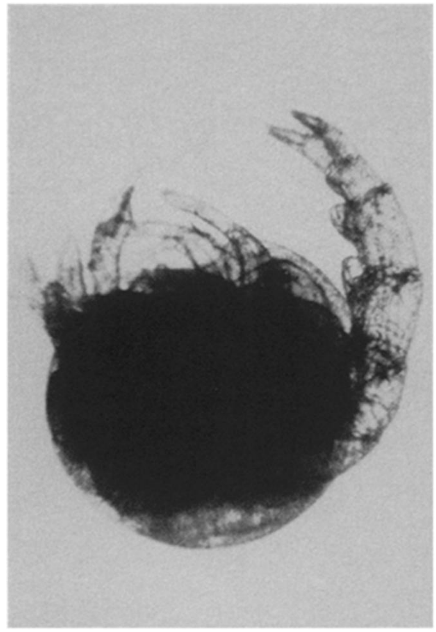
The first animal they considered was a tropical spider crab that had shown such enthusiasm for grazing on the museum reef's algae that it came to be regarded as something of a nuisance. "It turned out to be the perfect sea cow to eat our algae," Adey says.

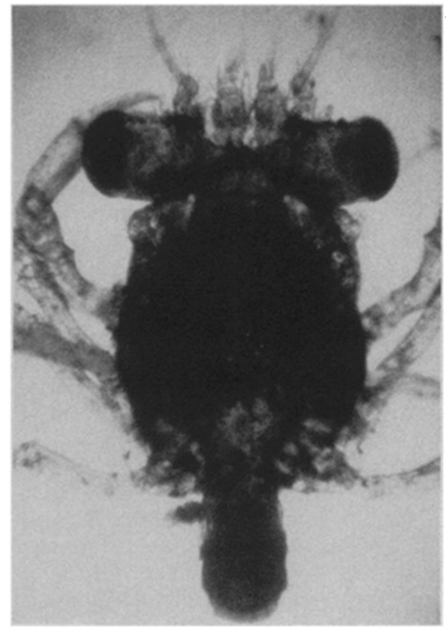
A stroke of luck accompanied this choice of a grazer. The spider crab was far simpler to sustain through its life cycle than are many other marine animals. It has a very simple childhood — after hatching from an egg, it lives as a free-swimming creature for only a few days, then settles into its sedentary adult lifestyle. Other marine animals spend months swimming free in a variety of larval forms that are difficult to support in mariculture.

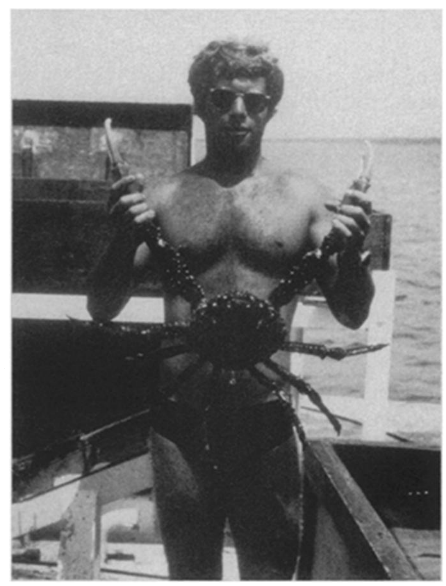
The scientists collect thousands of eggs from a captured female crab and allow them to hatch. The larvae are kept in tanks for several days, then about 200 juveniles are placed in open cages floating in the ocean. The cages hold screens of algal turf, upon which the young crabs graze. As the crabs grow, the scientists replace depleted screens with full ones and eventually reduce the number of crabs per cage to about 50.

After 250 days, each crab weighs about a pound and a half, most of the weight in meat, and is considered marketable. The optimal weight is about 5 pounds. Such adult crabs sell on the dock for $4 per pound. At this price, most of the immediate fruits of the harvest will not go to hungry islanders. However, Adey believes that a mariculture industry for export and tourist trade could be a boon to Caribbean fishermen, who currently are impoverished because the fish and shellfish have been depleted.

"It is expected that since hundreds of larger grazer species are present in coral reefs, many species can eventually be brought into the process, creating broad-spectrum, low-tech and low-cost food production systems for tropical maritime countries," Adey says. He estimates that the algal turf screens can serve as a basis for the raising of about 100 species by mariculture.







Early (left) and late larval forms of the tropical spider crab Mithrax spinosissimus. *At right, mariculture specialist Mitch Yadven displays a full-grown crab ready for market.*

Adey and his colleagues already have begun work on a second system — the large snail *Cittarium pica,* which is considered a delicacy on many Caribbean islands. Studies also are under way to bring a fish and a sea urchin into full mariculture.

The scientists, whose work is supported by the U.S. Agency for International Development and the Peace Corps, have already done some calculations on the potential impact of simple, inexpensive algal turf mariculture. Currently the screens supporting the algal turf cost $6 apiece, but Adey says the price could drop to about $1 if they were mass-produced. For the Caribbean king crab, they estimate 3,000 fishermen could be employed "more or less immediately," each one earning about $15,000 per year after an initial investment of about $5,000 per fisherman. For the first tests, the scientists' research grant will provide the initial investment for a few fishermen, and loans are expected to become available later for larger numbers of fishermen to buy the equipment required.

Some outside observers are skeptical about these economic projections and say that although the system is technically feasible, the commercial viability must still be demonstrated. The proposed procedures require much labor, including daily maintenance of screens and cages. This may require a major change in lifestyle for the traditional, more itinerant fishermen.

Around the globe, Adey suggests that algal turf mariculture is best suited for the trade wind seas — about 30 million square miles of the ocean surface. However, he cautions that the cost of open-ocean mariculture will be significantly higher than that in more protected regions.

What would widespread algal turf production cost in environmental terms? Adey argues that the price would be low. He says that massive algal turf mariculture in the eastern Caribbean and West Indies could produce 96 million metric tons of dry algae per year using the top 12 meters of ocean water. Because the nutrients would come only from this top layer, Adey says, it seems unlikely that any significant drop in nutrients elsewhere would result.

If the method fulfills its ambitious promise, fuzzy turfs of green, blue-green, brown and red algae riding the waves just below the ocean surface just might be the basis of a greening of the seas. □